Earthquake Catalogs for Hazard

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USGS Approach

- Use a mix of published, well-documented, national-scale source catalogs
- Dominated by NCEER-91 & PDE
- 1700-present
- m_{bLg}-based ($m_{bLg} \geq 3$ for PSHA)

Source Catalogs (1996, 2002, 2008)

- Special cases
  - ✓ special studies (Chapman 1916 Skyland, Spence 1882 Colorado, etc)
  - ✓ mining (Kentucky, Colorado, etc), explosions (nukes, etc), bogus eqks
- NCEER-91: 1627-1985, ~m_{bLg} ≥ ~2.5
  Seeber & Armbruster (1991) & updates
- "US History": 1774-1989, mag ≥ ~4.5 or MMI ≥ ~VI
  Stover & Coffman (1993)
- USGS State-by-State Catalogs: 1752-1986, mag ≥ ~2.5
  Stover, Reagor & Algermissen (1984)
- USGS PDE: 1960-present, mag ≥ ~2.5
- Decade of North American Geology: 1534-1985, mag ≥ ~3.0
  Engdahl & Rinehart (1991)
- New Mexico: 1963-1993, mag ≥ ~3.0
  Sanford and others (1995)

? Concerns when considering other source catalogs
  - Documentation
  - Magnitude consistency

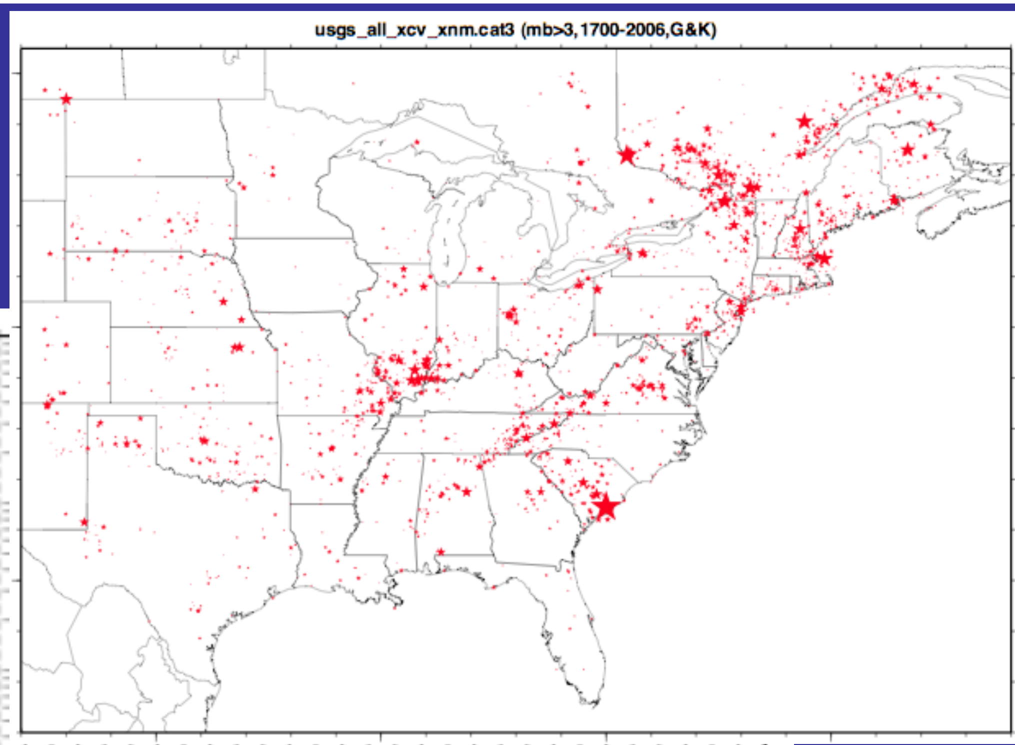
USGS science for a changing world

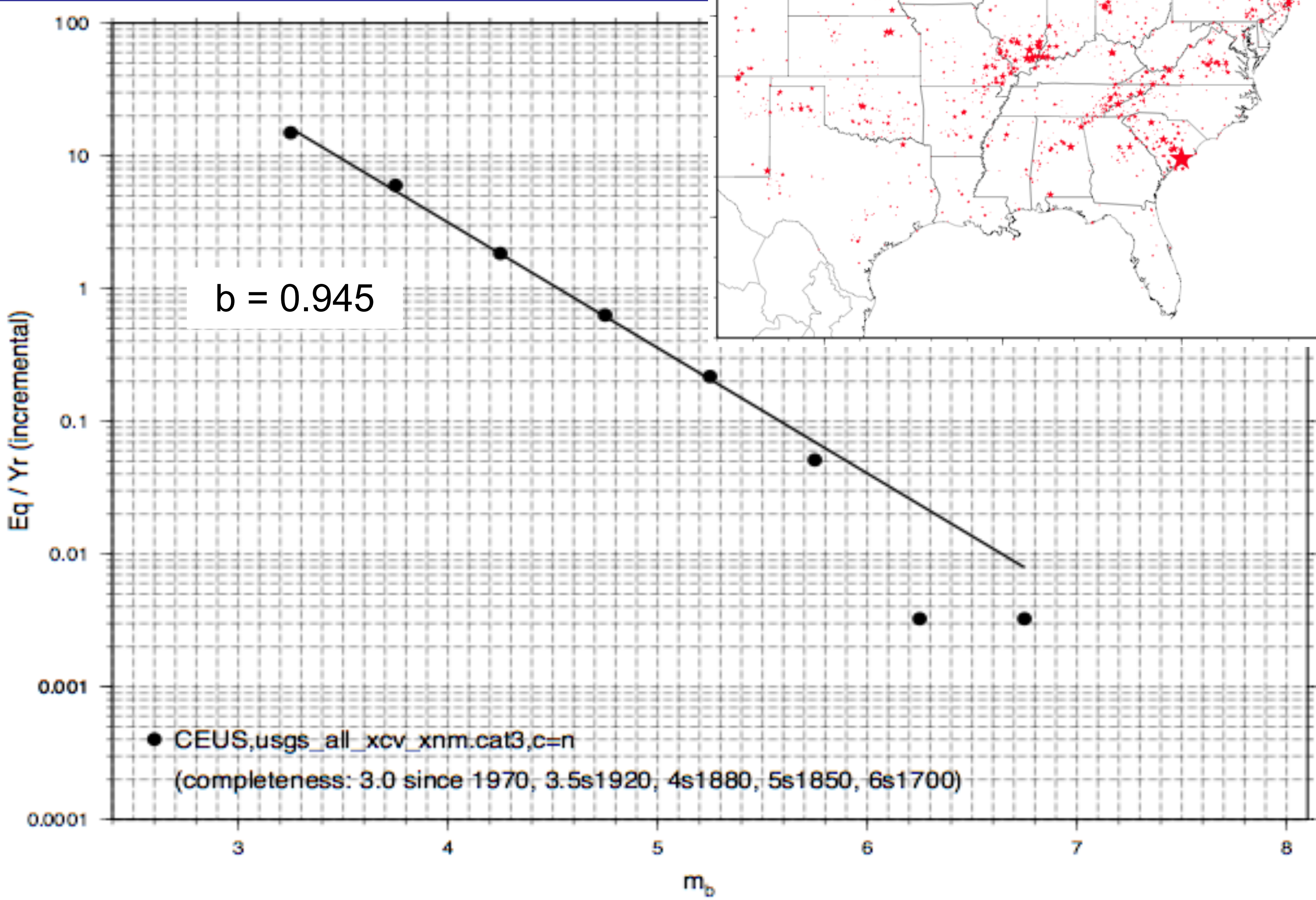
Procedure

1) Select single record (from among duplicates):
    1. Special Cases (<1%)
    2. NCEER-91 (71%)
    3. New Mexico (<1%)
    4. Stover & Coffman (<1%)
    5. SRA (7%)
    6. PDE (19%)
    7. DNAG (2%)
2) Select preferred magnitude & "convert" (if necessary - only about 15% do not have a listed m_b, m_{bLg}, or M_N)
3) Decluster (Gardner & Knopoff)
4) Remove man-made events if no hazard:
    - Ongoing seismogenic process, but hazardous events are not expected (e.g., Paradox Valley, most mining-related seismicity)
    - Seismogenic process no longer active (e.g., Rocky Mountain Arsenal)

2008 USGS m_b catalog

(3014 eqks: $m_b \geq 3$, 1700-2006, G&K)





2011 CEUS-SSC Catalog

3

CHAPTER 3
EARTHQUAKE CATALOG

This chapter describes the development of the earthquake catalog for the CEUS SSC Project. The catalog development consists of four major steps: catalog compilation, assessment of a uniform size measure to apply to each earthquake, identification of dependent earthquakes (catalog declustering), and an assessment of the completeness of the catalog as a function of location, time, and earthquake size. Each of these steps is described in detail in the chapter. The result is an earthquake catalog covering the entire study region defined in Chapter 1 for the time period of 1568 through the end of 2008. Earthquake size is defined in terms of the moment magnitude scale (Hanks and Kanamori, 1979), consistent with the magnitude scale used in modern ground motion prediction equations for CEUS earthquakes.

http://www.ceus-ssc.com/project_report.html

CEUS-SSC Approach

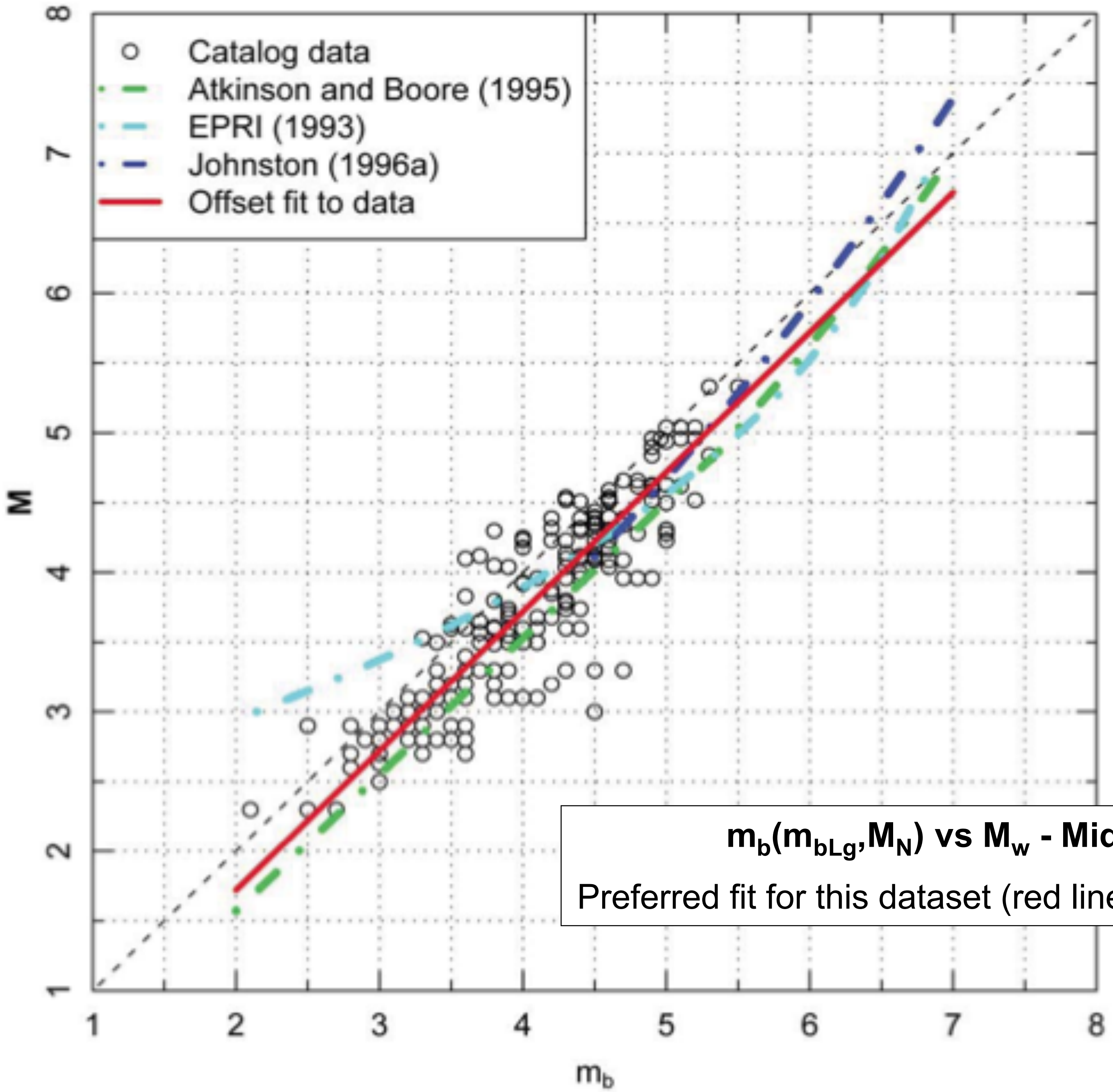
- Moment-magnitude
- Return to original sources
- Return to original intensity for older m_b & M_L
- Include more sources => smaller regional & local catalogs
- Non-tectonic events

CEUS-SSC - Source Catalog Hierarchy

1. Special studies
2. USGS-NSHMP & GSC
3. Regional/local net (CERI, Weston, SUSN, SLU, LDEO, SCSN, StateGS)
4. ANSS, Stover & Coffman, ISC

CEUS-SSC - Magnitudes

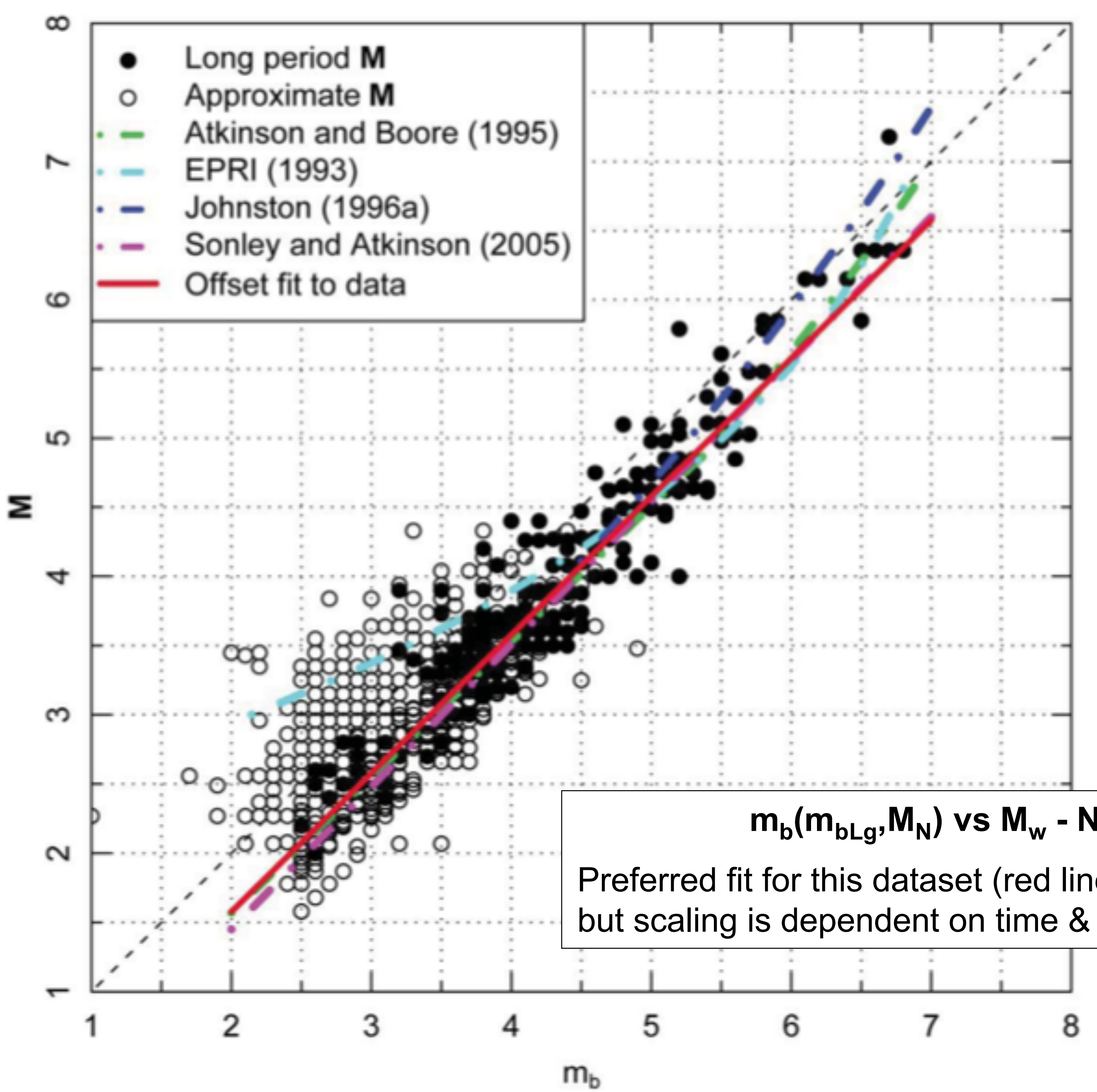
- Moment magnitude (M_W)
  - "True" M_w (waveform inversions)
  - "Approximate" M_w (Fourier spectra)
  - Conversions from other magnitude scales
- Appears complete down to M_w 2.5 east of about -100° for the past few decades



$m_b(m_{bLg},M_N)$ vs M_w - Midcontinent

Preferred fit for this dataset (red line) is $M_w = m_b - 0.28$

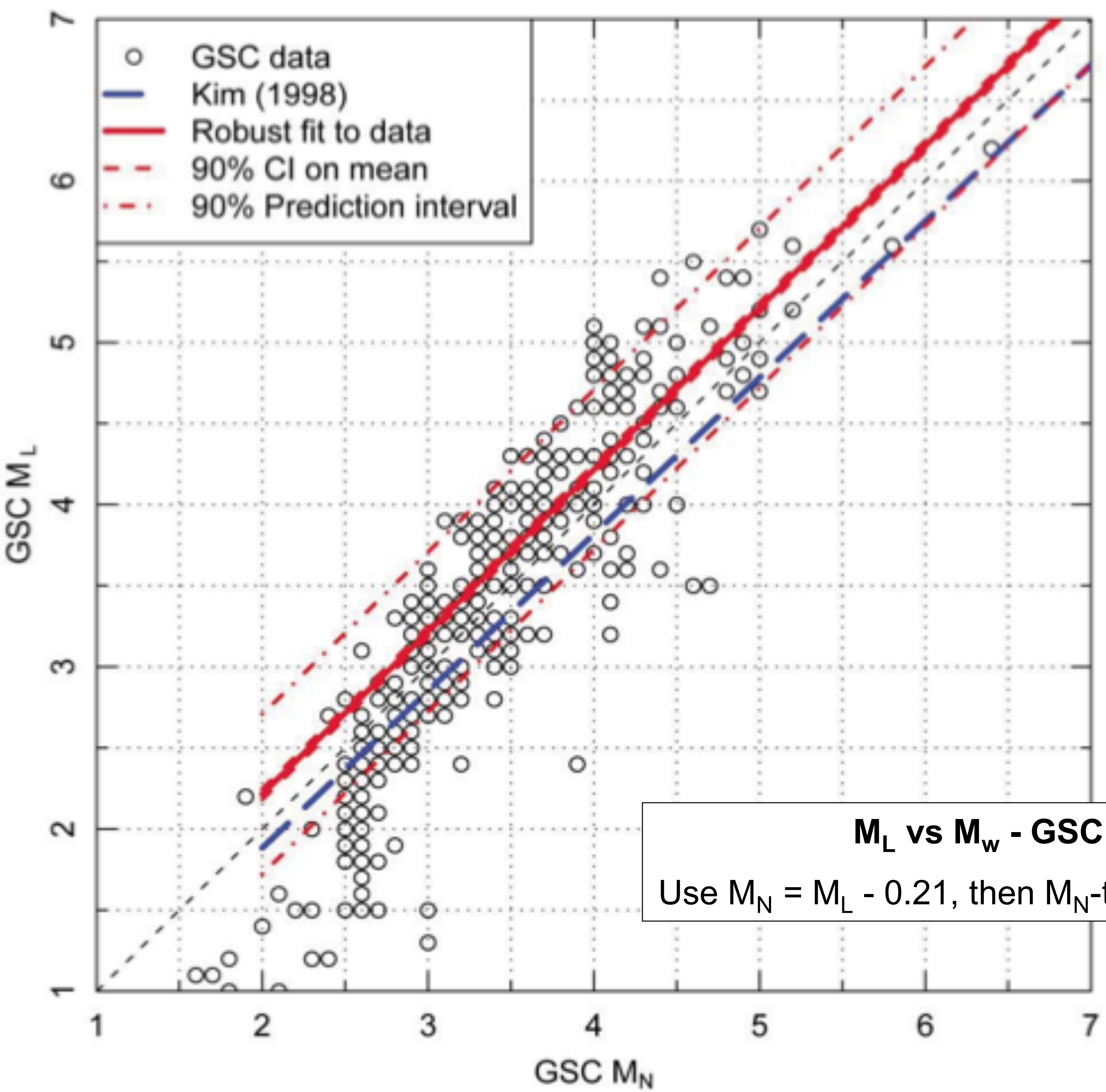
CEUS-SSC Fig 3.3-7



$m_b(m_{bLg},M_N)$ vs M_w - Northeast

Preferred fit for this dataset (red line) is $M_w = m_b - 0.42$, but scaling is dependent on time & source catalog

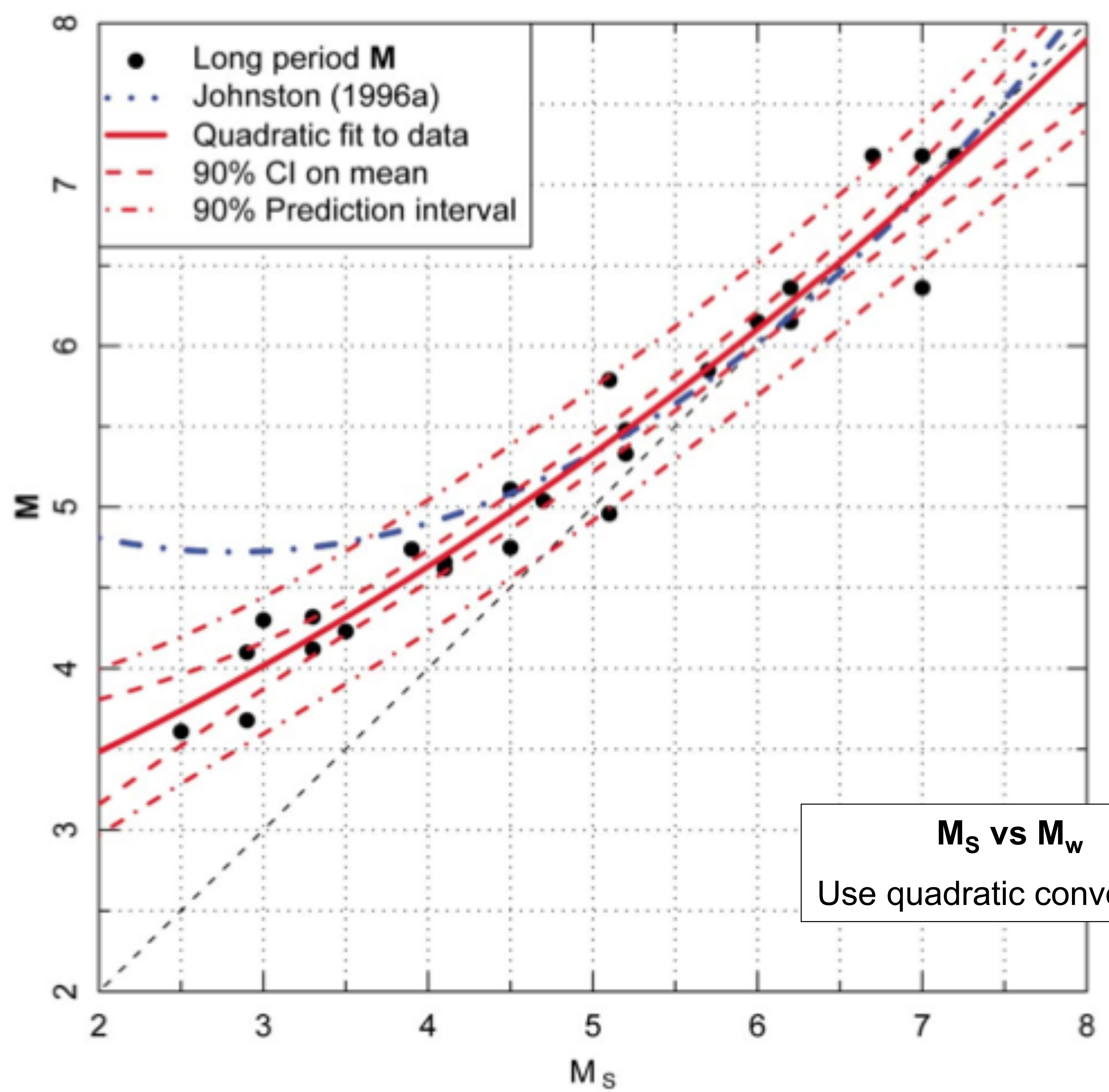
CEUS-SSC Fig 3.3-10



M_L vs M_w - GSC data

Use $M_N = M_L - 0.21$, then M_N-to-M_W conversion

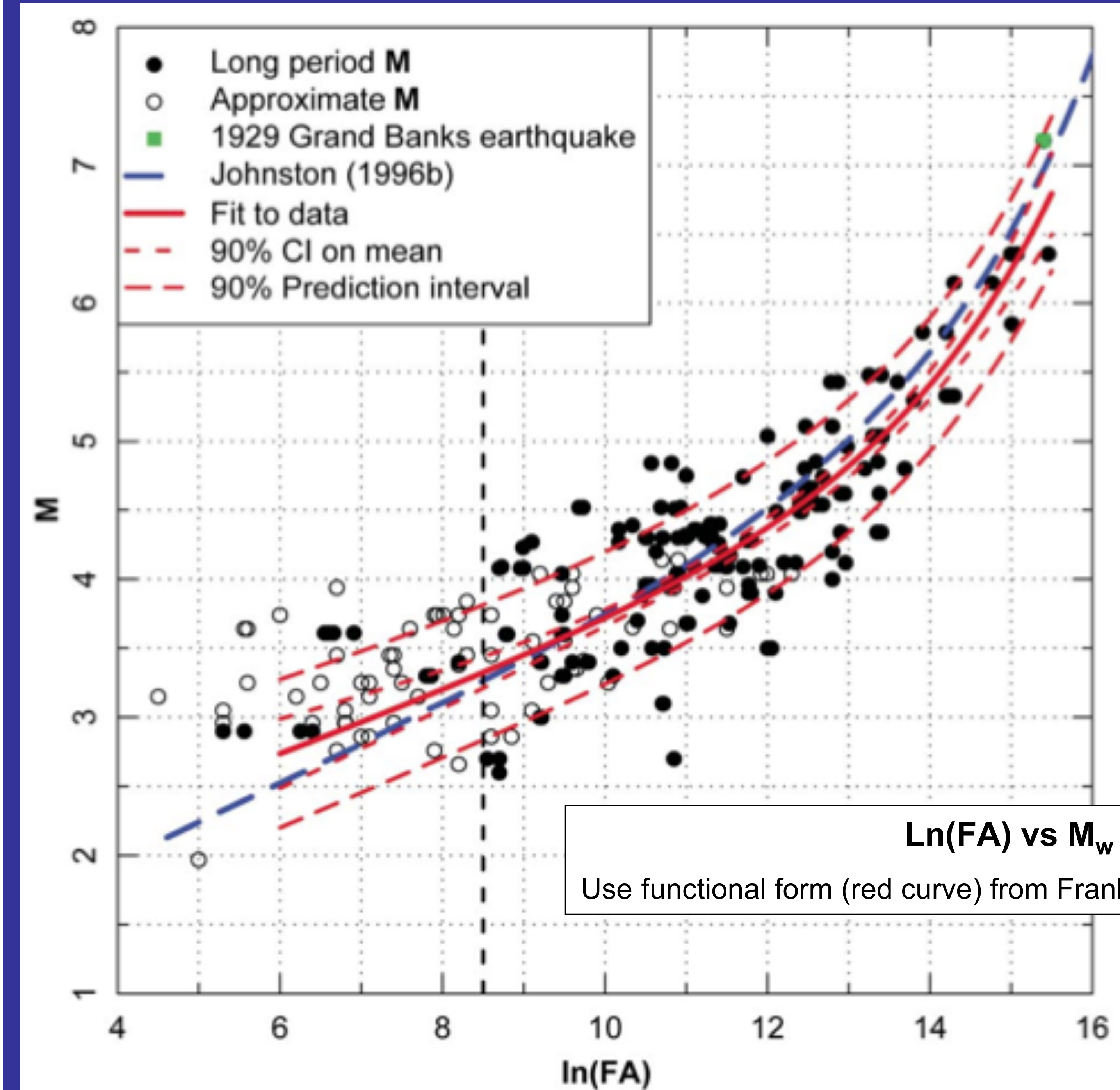
CEUS-SSC Fig 3.3-23



M_S vs M_w

Use quadratic conversion

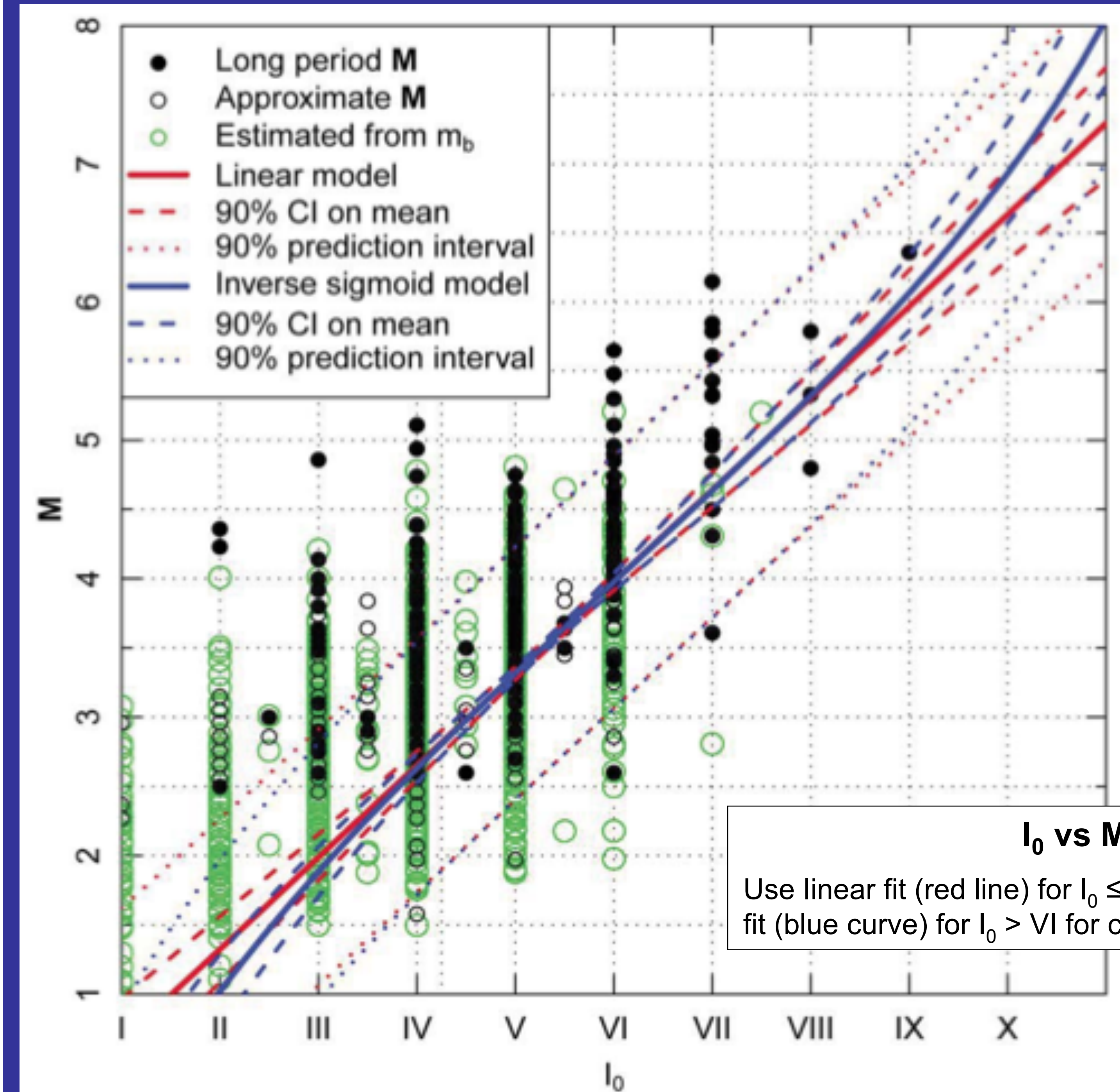
CEUS-SSC Fig 3.3-27



Ln(FA) vs M_w

Use functional form (red curve) from Frankel (1994) for conversion

CEUS-SSC Fig 3.3-44



I_0 vs M_w

Use linear fit (red line) for $I_0 \leq$ VI and inverse sigmoid fit (blue curve) for $I_0 >$ VI for conversion

CEUS-SSC Fig 3.3-55

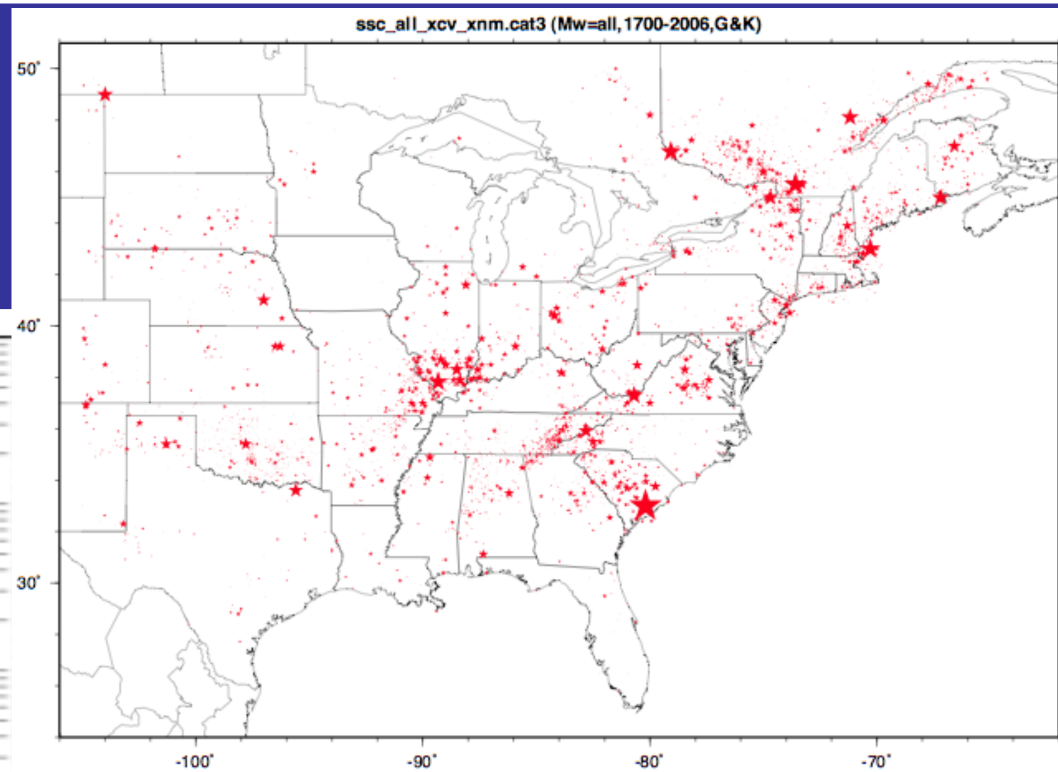
Table 3.3-1
Conversion Relationships Used–Develop Uniform Moment Magnitudes E[M]

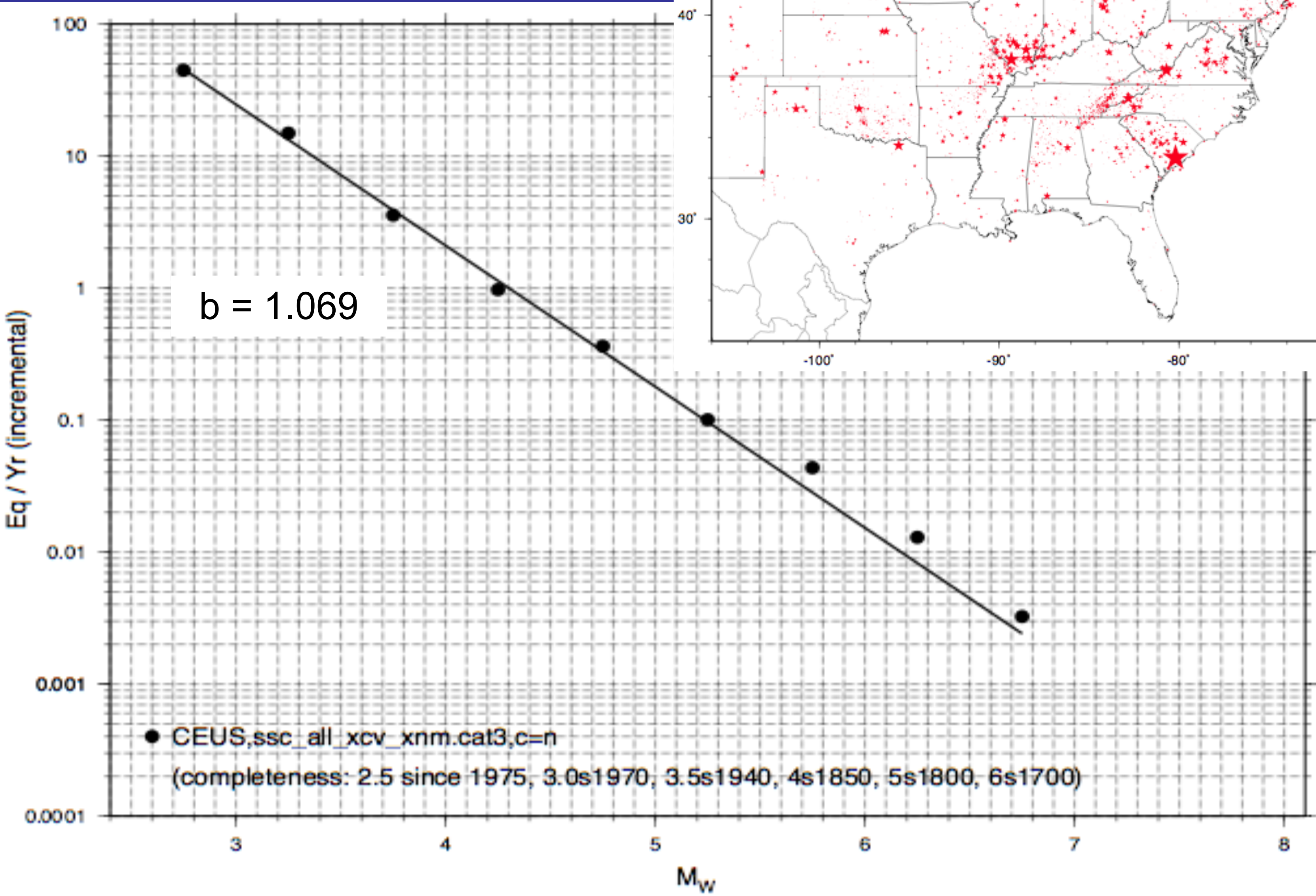
Size Measure	Conversion Relationship	$\sigma[\mathbf{M}\mid\mathbf{X}]$
Body-wave magnitude (m_b, m_{bLg}, $m_{Lg(f)}$, M_N)	$E[\mathbf{M}] = m_b - 0.316 - 0.118Z_{NE} - 0.192Z_{1997GSC} + 0.280Z_{1982NE}$ Z_{NE} = 1 for earthquakes located in the Northeast (northeast of the dashed line on Figure 3.3-16, including GSC data), and 0 otherwise $Z_{1997GSC}$ = 1 for earthquakes occurring after 1997 recorded by GSC, and 0 otherwise Z_{1982NE} = 1 for earthquakes occurring in the Northeast before 1982 recorded by other than GSC, and 0 otherwise	0.24
M_L reported by GSC	Compute $m_b = M_L - 0.21$ and use m_b conversion	0.42
M_S	$E[\mathbf{M}] = 2.654 + 0.334M_S + 0.040M_S^2$	0.20
M_C, M_D, M_L in northeastern United States (other than GSC)	$E[\mathbf{M}] = 0.633 + 0.806(M_C\ M_D \text{ or } M_L)$	0.27
M_C, M_D, M_L in midcontinent United States east of longitude 100°W	$E[\mathbf{M}] = 0.869 + 0.762\ (M_C, M_D, \text{ or } M_L)$	0.25
M_C, M_D, M_L in midcontinent United States west of longitude 100°W	Use m_b conversion	0.24
Ln(FA) (in km^2)	$E[\mathbf{M}] = 1.41 + 0.218 \times \ln(FA) + 0.00087\sqrt{FA}$	0.22
I_0	for $I_0 <= VI$ $E[\mathbf{M}] = 0.017 + 0.666I_0$ for $I_0 > VI$ $E[\mathbf{M}] = 4.008 + 3.411 \times \sqrt{2}Erf^{-1}\left[(I_0 - 6)/6.5\right]$	0.50

CEUS-SSC Tbl 3.3-1

CEUS-SSC M_W catalog

(5108 eqks: $M_W \geq 2.5$, 1700-2006, G&K)
(3424 eqks: $M_W \geq 2.7$, 1700-2006, G&K)





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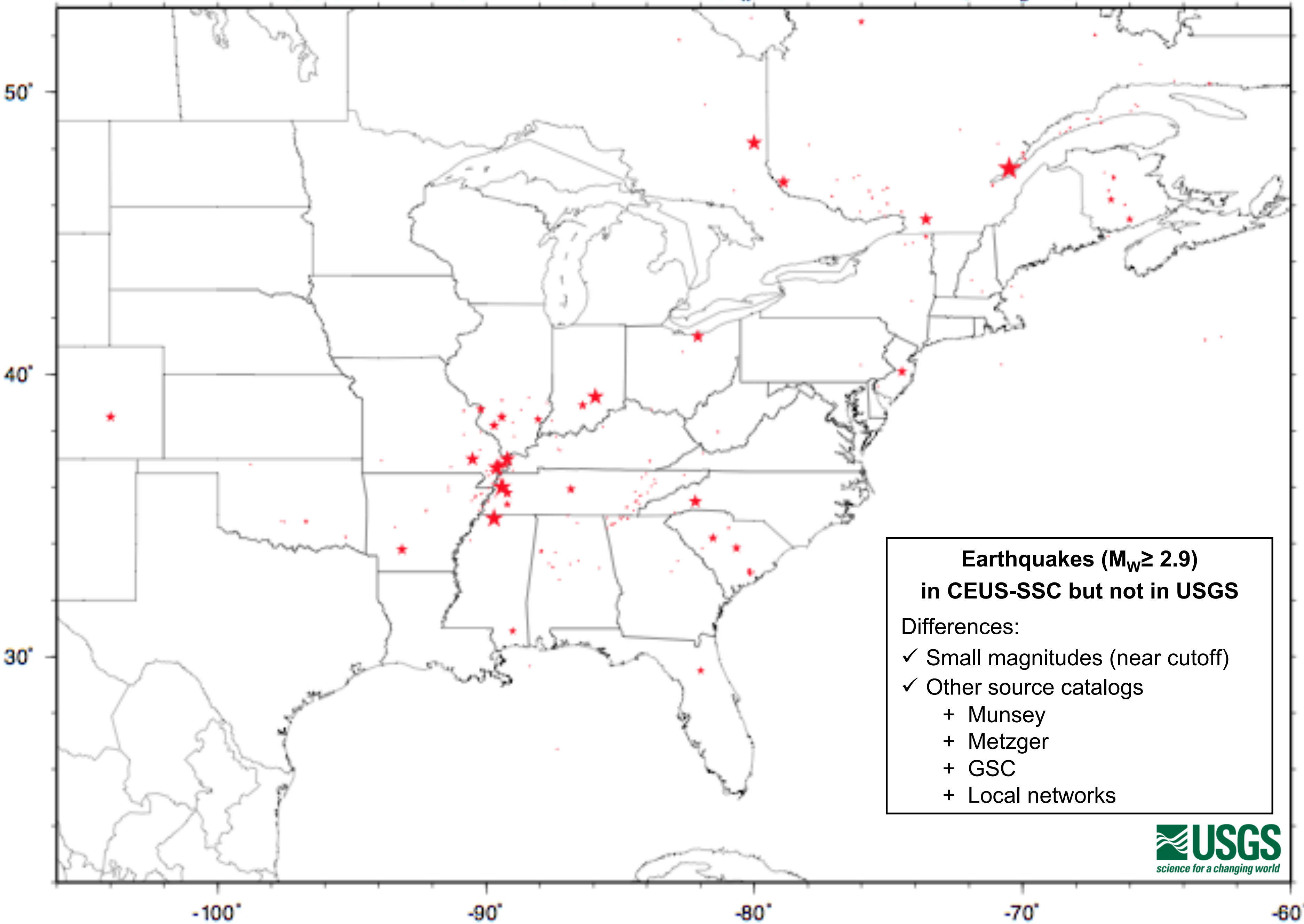
All			
USGS m_b		CEUS-SSC M_W	
$m_b \geq 3$	3014	$M_W \geq 2.7$	3424
$m_b \geq 5$	65	$M_W \geq 4.7$	83
		$M_W \geq 4.8$	67

Exclude Charlevoix & New Madrid			
USGS m_b		CEUS-SSC M_W	
$m_b \geq 3$	2643	$M_W \geq 2.7$	2886
$m_b \geq 5$	51	$M_W \geq 4.7$	65
		$M_W \geq 4.8$	51

Eqks (w/ ssc completeness): in ceus-ssc (M_w>=2.9) but not in usgs (m_b>=3)



Earthquakes ($M_W \geq 2.9$)
in CEUS-SSC but not in USGS

Differences:

✓ Small magnitudes (near cutoff)

✓ Other source catalogs

+ Munsey
+ Metzger
+ GSC
+ Local networks